
NEW TECHNOLOGIES IN CONSTRUCTING CONCRETE STRUCTURES



Bachelor's thesis

Degree Programme in Construction Engineering

Visamäki, Spring 2015

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Visamäki
Degree Programme in Construction Engineering
Steel Structures

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Subject of Bachelor's thesis	New technologies in constructing concrete structures.	

ABSTRACT

This Bachelor's thesis was commissioned by Avangard company. The purpose of the thesis was to gather information on the latest technologies used on a construction site during the process of erection of monolithic concrete structures. In order to estimate the general efficiency of those technologies they were compared to older technologies. The comparison criteria were the cost of transportation, cost of products, cost of using heavy machines, time of assembling and production and approximate time for all the process. To show detailed process of calculation and examining the construction process Ratu production data books were used.

All the information needed was collected from relevant internet sources. Building professionals and experts were interviewed via phone and e-mail.

Keywords concrete, new technologies, formwork, reinforcement

Pages 52 p. + appendices 0 p

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1 INTRODUCTION

1.1 What is concrete?

Concrete is an artificial stone made by human. The word “artificial” gives an idea that the human race created concrete, while imitating the nature. Looking closer at the nature helps to see how earth creates its own “concrete”. With time weather creates sediment from primary rocks or mountains. In most cases sediment consists of granular materials, which subsequently get fastened by a binder (for example silicic acid) to the “concrete”. Nowadays, concrete is well known as a composite material composed mainly of water, aggregates and cement. Admixtures and reinforcements can be used to improve the quality of the final material. Concrete is well known and used all around the world in the construction field because of its mechanical properties such as durability, fire resistance and formable material.

(Concrete History)

1.2 History of concrete

It is hard to say exactly when the first concrete structure appeared in history. Concrete as a material that can be used nowadays is not something that people had before. As almost anything on earth concrete went through a long way of development.

The first appearance happened 12 million BC. Israel was the first place where during spontaneous combustion reactions between limestone and oil shale occurred to form a natural deposit of cement compounds. Three thousand BC Egyptians used mud mixed with straw to bind dried bricks.

One of the first people who used concrete in construction are the Chinese. The preparation of concrete has easy steps. First, one part of lime is mixed with two parts of sand and gravel or just with sand, debris and earth. Second, the dry mixture combined with a small amount of water which is stacked in layers with the thickness of 12 cm between the wooden formwork. Third, the layer is lightly moistened with water. This process was repeated until the entire wall was done.

Approximately, by 500 BC, the knowledge of producing concrete structures gradually spread in the Eastern Mediterranean and reached the ancient Greece. For covering walls Greeks used not just rubble masonry, but also fine-grained limestone concrete. As an example, for military prepuces Greeks were building mortared rubble walls used for defiance. The architect and engineer Vitruvius describes several types of similar walls in his works.

A noticeable use of concrete in the territory of the Roman state began around the end of the IV. BC and lasted for about 700 years. However, the Romans moved forward with building concrete structures using the

knowledge of Greeks. In addition, Greek influence can be seen in Roman's architecture. They were successfully creating art pieces, such as the Colosseum, aqueducts of Rome, the Baths of Diocletian and the Baths of Caracalla. Some of these stunning creations people can see even nowadays. A slow and gradual birth of concrete technologies in a Roman building practice lasted more than two centuries. Then amount of concrete construction throughout the Roman Empire started to grow widely for around 300 years. Later on concrete did not develop so rapidly, but it was noticeably improving its properties. Manufacturing technology and new design solutions got improved, too. This period lasted for about 100 years. Finally, in the IV century BC Roman Empire fallen and technologies of producing concrete were lost for a very long time.

After a long time in 1756 a British engineer John Smeaton made the first steps towards invention of Portland cement, which led to the rebirth of concrete as people know it nowadays. He designed the third Eddystone Lighthouse. The most important part of this project which affected the progress of the concrete in the future is the use of hydraulic lime (adding also coarse aggregate and powdered brick to the mixture) in concrete.

One of the next steps towards the re-emergence of concrete was made by a British businessman and cement manufacturer Joseph Aspdin. From 1817 he was experimenting with cement manufacture until 1824, when he got a British Patent for the method of producing Portland cement. He also invented the name "Portland cement".

A very important stage in history of concrete became the year 1849, when a French gardener opened small workshop, where he could work with landscaping projects. His name was Joseph Monier and he was one of the pioneers who were experimenting with reinforcement. Monier was working as a gardener and wasn't satisfied with the materials available for making flowerpots. He started to make pots and tubes from concrete and to make it stronger he started to experiment with reinforcement. Later on he promoted it and showed it at Paris Exhibition of 1867. The same year Joseph Monier obtained his first Patent. After all, this reinforced concrete started to grow and progress as a technology and the first reinforced concrete structure was bridge and it was built in 1889 in America. The name of the bridge is Alvord Lake Bridge. (Concrete History, Joseph Monier; Joseph Aspdin)

2 RATU

Ratu is the provider of construction information in Finland. The Group consists of the Building Information Foundation RTS, which is the parent company and acts as the R&D unit for the whole group, and Building Information Ltd, which is the publishing house owned by the Foundation. (Rakennustieto)

One of the main books, which gather knowledge of different construction companies are Production Data book, Quality Manual book and Safety Manual book.

2.1 Production Data

In the RATU Production data book are collected data on material and labor costs, separated according to the list of works Talo 90. The book presents in parallel as cost data for new construction and renovation. If labor and consumption of materials on the subject of reconstruction has not been announced, it is possible to use data on labor costs for new construction. In this case, however, should be taken into account the special characteristics of the object of reconstruction, for example, the protection of existing structures and limited space site.

Each chapter for each work consists of different tables and explanations. First on the page (Figure 1) is the name of chapter and list of works this chapter consists of. Then on the page is located one of the main parts for calculations. It is T3 labor time table. Data on labor costs by type of work is divided into two columns, of which the left shows the data on labor costs at the site of new construction, during the working period T3. The right column shows, respectively, labor T3 on the subject of reconstruction, in particular, the cost of dismantling, improvement and replacement. Labor costs are shown as the number of man-hours per unit, for example ph / m. or ph m / m². Each value is based on a specific scope of work described in the routing RATU, to which reference is made. Content operations may vary depending on the subject, and thus, for the various components are given different jobs or alternative labor. During the work shift T3 is obtained by adding all of the constituent work on the project. In this case, all the unit labor costs in all aspects of the work should be the same.

78		51 Работы по монтажу деревянного каркаса	
51 Работы по монтажу деревянного каркаса			
Объект нового строительства Исходное состояние: Фундаменты, простеры и принты. На объекте строительства имеются необходимые материалы, механизмы и оборудование. Общественный материал погрузочно-разгрузочный. Содержание работы: - изготовление стен деревянного каркаса - обшивка подвального, чердачного и чердачного перекрытий - изготовление деревянных конструкций крыши, а также - деревянная обшивка фасадов, включая переобшивку и/или Конечное состояние: Работа по монтажу деревянного каркаса готова, простера и принты. Проведена уборка, мусор рассортирован. Материалы находятся на объекте.		Объект реконструкции Исходное состояние: Конструкции, подлежащие разборке, демонтированы. На объекте строительства имеются необходимые материалы, механизмы и оборудование. Содержание работы: - демонтаж, восстановление и ремонт конструкций крыши. Конечное состояние: Работа по демонтажу, восстановлению и ремонту деревянных конструкций крыши готова, простера и принты. Проведена уборка и мусор рассортирован. Лишние материалы, механизмы и оборудование находятся на объекте.	
Трудоуказы Т3 на объекте нового строительства		Трудоуказы Т3 на объекте реконструкции	
Сооружение стен деревянного каркаса чм/м ² - простой каркас (600) 0,34 - каркас (600) с дополнительной обшивкой 0,51 - простой каркас, выложенный по шпилькам методом, включая ветрозащитные плиты 0,36 Обшивка подвального перекрытия - простая обшивка 0,22 - наклонная обшивка 0,40 - простая обшивка шпильками методом 0,32 - наклонная обшивка шпильками методом 0,42 Обшивка чердачного перекрытия - традиционная обшивка 0,45 - обшивка шпильками методом 0,33 Обшивка чердачного перекрытия - традиционная обшивка 0,45 - обшивка шпильками методом 0,43 Конструкции крыши - потолочные балки 0,19 - стропильная конструкция 0,13 чм/м: м - конструкция стропил 0,42 чм/м: м - потолочные балки шпильками методом 0,55 чм / шт. - конструкция стропил шпильками методом 0,52 чм/м: м - сплошная обшивка досками 0,21 - редкая обшивка досками 0,13 - изготовление стропил 0,15 Деревянная обшивка фасада - 1 рядовая обшивка, обшивка шпильками доской 0,39 - 2 рядовая обшивка, обшивка шпильками доской 0,42 - 1 рядовая обшивка, обшивка нащельными планками 0,59 - 2 рядовая обшивка, обшивка нащельными планками 0,61		Ремонт, демонтаж и изготовление вновь конструктивных элементов - ремонт конструкций крыши 0,40 чм/м ² - демонтаж конструкций крыши 0,27 чм/м ² - изготовление вновь конструкций крыши 0,72 чм/м ² - демонтаж только нижней обшивки 0,05 чм/м ² - сооружение вновь только нижней обшивки - редкая 0,25 чм/м ² - частая 0,45 чм/м ²	

Figure 1 First page. Example for one type of works.

On the second page (Figure 2) first can be seen additional information. It gives more information about the types of work outlined in card technology and labor and material costs Ratu, which are listed at the top right of the page turn. In technological maps Ratu presents the most important data on labor costs, material costs and loss.

Very important role takes the TL3 coefficient. Labor costs specified in the book are the work shift or time period T3. At the location of the header at the top of the right-hand page shows the coefficients of extra time TL3 on the types of works in new construction and renovation. It gives more clear time needed for works to be done.

At every turn of the page on the right shows the factors affecting labor costs, as well as their coefficients, in particular:

- The total amount of work on the project
- Average amount of work
- The impact of the winter period of the work

The scope of work has an impact on labor costs in the project so that labor costs per unit decrease with increasing quantities. Production work in the winter, in turn, increases the labor, because working in winter conditions cause extra work, in and of themselves winter conditions slow down the work.

The chapter with cost of materials shows the theoretical cost of essential materials, as well as the total loss of materials. The theoretical consumption of materials presented at the unit is for example, $\text{rm. m} / \text{m}^2$. The total loss M5 is shown in percentage of the theoretical flow rate.

Data on labor costs of this book are shown as the effective time or time shift T3. The time shift gives target labor costs, which do not include interference or suspension lasting more than an hour. Effective time is used for making construction schedules, weekly schedules and plans for implementing tasks.

The total time or run-time phase of work includes all the hours spent at work, as well as suspension of work, lasting an hour or more. The total time is used to determine the costs and making general graphs. The total time is calculated by multiplying the time by a factor of a working shift TL3. TL3 factor is specified for each type of work.

Additional time working stage is a stop that lasts about an hour, including small individual working steps, breaking machines or equipment, the time for their maintenance, downtime, unsuitable weather conditions, accidents and so on. TL3 ratio ranges between 1.10 and 1.30 depending on the type of work. Frosty days in extra time working stage are not included.

7

In this book information about quality in each chapter is divided into three parts as follows:

- Each chapter contains the following information which can be used to proceed quality control:

- A group of works. The book presents all kinds of works from the list of names of different types of works from "Talo 90", with 8 groups. The section for each group of works begins with a general description of the group (Figure 3). The first page lists the types of work, included in this group, and possibly jobs, divided into parts. At the end of the page Ratu-instructions are published for this type of work for construction and repair.

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- Planning of tasks. On the second page (Figure 4) in the upper section considers the formation of complex production scheduling tasks on a group of works, sources and content of planning. At the bottom of the page in a narrow column is listed the instruction brochure "production planning: subcontract, works that have to be completed according to quality manual" on this group of works.

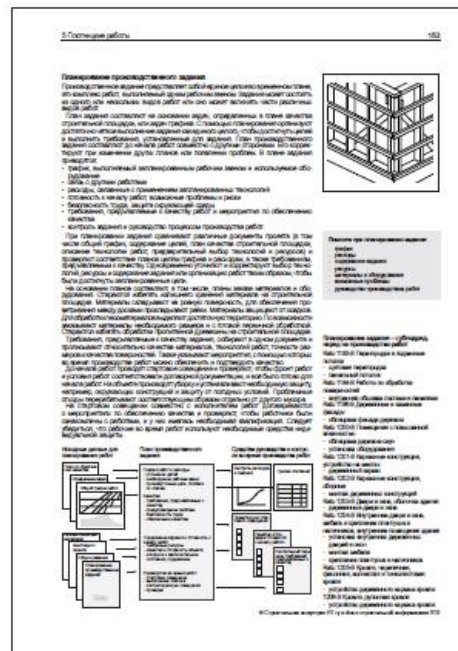


Figure 4 Second page. Formation of complex production scheduling, group of works, sources, content of planning and instruction brochure

- Title. "Title" page (Figure 5) represents determination of the type of work and the description of the quality requirements of the type of work as listed in "Talo 90". For clarity, in the "Title" there is a drawing of a central stage of a certain type of work.

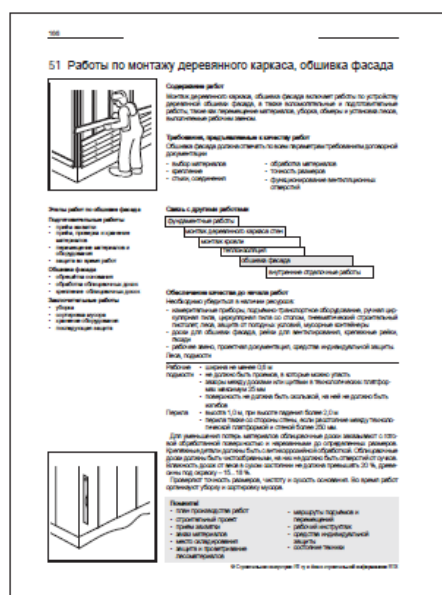


Figure 5 "Title" page

checks of the quality of the finished work. These are, for example, distribution, organization of follow-up care for necessary protection, as well as assessments of quality. In the quality control the materials used and methods of work, dimensional accuracy, surface quality and functionality are checked.

- Technical requirements to the quality of work (Figure 7). Technical requirements to the quality of work are collected from different sources. The most important sources are the “General requirements for the quality of construction 2000” or RYL 2000 and instructions of RT. The most important questions are presented in the tables. For other sources of the quality requirements references can be used. The requirements for the quality are divided into: the base, the materials, equipment and finished work.

188 91 Работы по монтажу железобетонных конструкций

Технические требования, предъявляемые к качеству бетонных конструкций

Инструменты	Минимальная толщина бетонной плиты (РД 102/11, 2000, таблица 9.12.1)
Калибры, шаблоны, измерительные инструменты	толщина плиты
от 10 до 100 мм	от 10 до 100 мм
от 100 до 150 мм	от 100 до 150 мм
от 150 до 200 мм	от 150 до 200 мм
от 200 до 250 мм	от 200 до 250 мм
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от 9100 до 9150 мм	от 9100 до 9150 мм
от 9150 до 9200 мм	от 9150 до 9200 мм
от 9200 до 9250 мм	от 9200 до 9250 мм
от 9250 до 9300 мм	от 9250 до 9300 мм
от 9300 до 9350 мм	от 9300 до 9350 мм
от 9350 до 9400 мм	от 9350 до 9400 мм
от 9400 до 9450 мм	от 9400 до 9450 мм
от 9450 до 9500 мм	от 9450 до 9500 мм
от 9500 до 9550 мм	от 9500 до 9550 мм
от 9550 до 9600 мм	от 9550 до 9600 мм
от 9600 до 9650 мм	от 9600 до 9650 мм
от 9650 до 9700 мм	от 9650 до 9700 мм
от 9700 до 9750 мм	от 9700 до 9750 мм
от 9750 до 9800 мм	от 9750 до 9800 мм
от 9800 до 9850 мм	от 9800 до 9850 мм
от 9850 до 9900 мм	от 9850 до 9900 мм
от 9900 до 9950 мм	от 9900 до 9950 мм
от 9950 до 10000 мм	от 9950 до 10000 мм

Потребность в работе

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Figure 7 Technical requirements to the quality of work

- Checklist (Figure 8). Checklist is a tool to ensure the quality of the work; it helps in the distribution of responsibilities before work, during and during transmission of works. A list is recommended to be used as the quality document and comment on the quality system of the organization.

When assessing a preparation level for work the following have to be checked:

- The availability and quality required by the previous stages of work
- Conditions for the beginning of work
- Safety at working place
- Working team / unit, materials, tools and equipment, storage and transportation of materials on a building site
- Documentation required on site, eg., Drawings, planned documentation, description of work technology, regulations and safety instructions, admission to special works and announcements

The main focus in the book "Quality Manual 2005" is on the quality of performance of work and on the execution of the established requirements. When evaluating the quality of performance quality of the working process and the final quality of the finished product are checked. They serve one goal: the quality of the final product appears easier and more economical if the production process is in order.

2.3 Safety Manual

On the construction site each person has the obligation to comply with safety regulations. Workers and other participants on a construction site are required to work and act together and inform about everything that concerns the safety and cooperative works on the construction site. Information described below is taken from RATU book of safety.

An employer or person has the primary authority to look for safety on the construction site. He has to ensure the construction site with the following things:

- Every employer and worker should be provided with briefing on safety and necessary information about the risks associated with work, fire protection measures and first aid.
- Coordination of actions of all constructors.
- Organization of the movement of different equipment, heavy machines and workers on the construction site.
- Order and cleanliness, according to healthy and safe working conditions.
- Other overall planning.
- Safe and healthy working conditions and working environment.

The tasks and responsibilities to comply with the general safety at the construction site are mainly defined in the legislation, but they concretized by a contract made between parties. Below can be seen table 1 with notifications, table 2 with risks, table 3 about organization plan of construction and table 4 about practical use of safety rules on the construction site.

Table 1

Task	Responsible person	Result	Additional information
Send notification to occupational safety officer	Prime contractor	Notification about construction works	Duration is more than 1 month. General number of workers not less than 10
Choosing occupational safety officer	Prime contractor	Occupational safety officer on the construction site	Should be always chosen
Choosing two alternate occupational safety officers	Construction workers	Alternate occupational safety officer on the construction site	Should be always chosen if general number of workers is more than 10

Table 2

Evaluation of risk of the construction plan	Developer	Documentation concerning safety	Specific risks of the project, results reporting
Evaluation of risk of different type of works	Prime contractor and contractor	Statement of Work, plan to ensure a safe work environment	Dangers at work, actions to be taken
Special planning of dangerous types of work	Prime contractor and specified contractor	Plan for avoiding and protection from falling, project of production of prefabricated structures, explosive works plan, disassembling plan, plan for elevating people	If necessary, constructor is presented

Evaluation of risk on the construction site	Prime contractor	Charting risks at the construction site of most dangerous areas	Dangerous stages of work, tasks, necessary additional plans
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Table 3

Task	Responsible person	Result	Additional information
Operating plan of construction site	Prime contractor	The plan of the construction site; making updates in accordance with construction stage	Preparation of premises, territories, etc.: utility rooms, storage areas, walkways, electrification, stationary jobs, garbage collection, fire safety, cranes
Harmonization of construction stages between each other	Prime contractor	Schedule of construction site	Providing safe working environment
Purchase equipment and machinery	Employer	-	When choosing should take into account safety issues (operation, ergonomics, noise, vibration)

Table 4

Induction	Prime contractor	Instructions for induction; documentation on induction training	Organization of the construction site, first aid, personal protective equipment, fire security, qualification
Briefing	Employer	-	The requirements for qualification, safety instructions
Safety instructions	Employer	Admission to works with fire, certificate confirming the passage of the safety briefing	-

Checking the safety at construction site	Prime contractor, occupational safety officer	Weekly checks, security risk analysis	-
Other necessary checks of safety at construction site	Constructor	Periodic inspections and checks on commissioning	The employer is responsible for safety checks on their sites and for the safe operation of the equipment, prime contractor is responsible for the inspection of equipment which is in use, eg., scaffoldings.
Cooperative work safety maintenance	All workers	Agreed cooperation and reporting of information	-
Discussions about safety at meetings	Prime contractor	Safety matters discussed at each meeting	-

Safety Manual provides with 48 instructions, one page each, of safety rules for different types of work. The instructions cover all types of work listed in the book Talo - 90.

Instructions are provided to each worker when:

- Worker gets familiar with the construction project.
- Worker begins to do the job that he never did before.

Some of the risks are generally specific to the construction project. Assessment and removal must be performed in accordance with each case. When the person responsible for the briefing, instructs workers, he should simultaneously discuss the risks associated with works that have to be done.

The worker writes risks that, in his opinion, are associated with this type of work on the empty lines of the form that is given to him. If filling out the form seems uncomfortable at the briefing, the worker is asked to return the completed form on the next day.

When a worker returns the completed form, the instructor holds a conversation about the dangers and how to prevent danger situations. A construction manager or the person responsible for briefing can make a copy of the completed form, the original form remains with the worker.

[illegible]

Most innovations brought by international countries come from the western world. In Russia modern technologies are fully used for construction of big projects or non-standard objects, which have social importance. After experiencing new technology it can be applied for construction of typical buildings. Thus, innovative methods are becoming publicly available.

3.1 Formwork

In construction formwork represents a set of different details and elements which form future repeated structures, such as walls, columns, ceilings and more. Formwork systems are delivered to a construction site unassembled. Their installation is done manually and with the help of scaffoldings and cranes. The formwork which is done manually is usually applied where it is impossible to set equipment, for example, in places of dense construction.

A non-removable formwork in modern construction is a hybrid method of wall construction with the use of large-size panels or hollow blocks made of certain material. With this technology blocks or panels perform the role of formwork and when the concrete is getting hardened, blocks or panels are not removed. They become part of the structure. This kind of formwork systems are commonly used in construction of small industrial buildings and residential houses. Most houses built with the use of non-removable formwork systems have a limited number of floors. However, such a formwork system has great advantages. It is easy to install, lightweight and has no need using heavy equipment. The most famous type of this system is Non-removable formwork blocks.

The removable formwork system contains large sized elements which can form the needed structure of the future construction. After concrete getting hardened, the formwork is removed. The installation process is very quick and easy, which helps to save a lot of time. Another advantage of such technology is that the system can be used many times. Details of removable formwork can be replaced if needed. Modern systems of removable formworks could be divided into three categories. Removable formwork systems must have a high structural strength, resistance to stress and mechanical stress and satisfy the requirements for durability and reliability. The material for removable formwork systems must have a high degree of resistance to deformation and bearing capacity. Therefore, in large part of such formworks galvanized or galvanized powder-coated steel is used. The coating is used to protect against corrosion and it provides a quick clean-up. In modern systems of removable formworks there are two types: removable and non-removable.

(Formwork)

3.1.1 Frame formwork system

A frame formwork system is a collection of framed panels, couplers and retaining elements. The basis of this formwork system is a framed panel, which consists of stiffeners, bearing metal frame (steel or aluminum) and

the shuttering boards. Bearing metal frame ensures the necessary stiffness of elements and it resists tensional stress and greatly simplifies insulation. A closed profile frame provides the reliable connection of elements at any place and protects the ends of a formwork from different kinds of damage.

The connection of elements of a framed formwork system can be done perpendicular and at different angles. Manufacturers pay great attention to the production of convenient couplers, which allow to have a solid and reliable connection. Attachment elements between the joints must withstand high mechanical stresses, such as compression, bending or stretching.

For shuttering boards laminated plywood most commonly used. Since plywood is a wooden material it needs frequent repair and replacement. The number of times plywood can be used depends on its consistency and thickness. Today a lot of research is done to find an alternative option for laminated plywood. One of the options is a special panel created by German specialists. The panel contains a layer of polypropylene coated with aluminum sheets on both sides, which are covered with special polypropylene-PP.

One example of a framed formwork system is TRIO Panel formwork (Figure 10) by PERI. Information about TRIO system can be found in the official website of PERI. TRIO is a universal formwork system which places the highest emphasis on uncomplicated forming operations and the reduction of shuttering times. With the BFD coupler for all connections and many other system solutions, TRIO has successfully proven itself in the 25 years since it was introduced to the market. It is easy and simple for installation, because it has only one connection part – the BFD alignment coupler.

Technical details can also be found from PERI's website (http://www.peri.com/en/solutions/products/formwork-systems/wall-formwork/trio_wand.cfm). The following lists the technical details:

- 6 panel heights from 0.30 m to 2.70 m and 5 panel widths minimize filler timber requirements
- Maximum permissible fresh concrete pressure 80 kN/m²
- Can be used with DW 15 and DW 20 tie systems
- Panels can be used both horizontally and vertically
- System components available for wall connections, T-junctions and corners
- Brackets and platforms available for ensuring safe working conditions
- Powder-coating of elements makes cleaning easier



Figure 10 TRIO panel formwork – a universal formwork system (http://www.peri.com/en/solutions/products/formwork-systems/wall-formwork/trio_wand.cfm)

3.1.2 Beam formwork system

The beam formwork system consists of a set of different structural elements, - scaffoldings for concrete, connection element, separate boards and beams and retaining elements. Basic elements are beams with a normalized size, which are made of wood. Beams are attached to the boards by structural elements made of steel. To increase operational properties plastic tips can be installed to the ends of the beams. They protect beams from damage.

One example of such a formwork system is the product of a company called MESA. The name of the product is H20P – Plywood Wall form system (Figure 11). H20P - Plywood Wall Form System consists of plywood as surface exposed to concrete and panels made of H20 timber beam and steel walers as support. This combination lightens the form. H20 wall form stands out as the lightest system among all similar form systems. Panels can be designed in a manner that they can resist the required concrete pressure between 40 kN/m² and 80kN/m² by changing connection intervals of the supporting components. The panels can be connected to each other side by side or as overlapped or at corners with connection details that can be applied easily. Angular parts and adaptor panels are available for various applications. Standard panels are manufactured with 250 mm intervals starting from 1000 mm and going up to 2500 mm. They can also be used for concreting of high walls. For retaining walls, foundation walls and dam walls, single-sided wall form can also be used tanks to the reinforcing system designed for such applications.

This system has enough advantages to satisfy and even impress constructors. With a clever design an easy application can be ensured. Varieties of different sizes of elements can provide flexible adaptation to different projects. Also, it can be used with other formworks. The lightness of the structure allows working with a low crane capacity. An easy connection with elements of this system provides easy assembly, which can be done

on-site. The combination of all those advantages can save money during the working process.



Figure 11 H20P Plywood form system by MESA
(<http://www.mesaimalat.com/en/h20p-plywood-column-form-system>)

3.1.3 Tunnel formwork system

The main element of the Tunnel formwork system is a semi section. This element consists of vertical and horizontal panels. In most cases the formwork itself is used for mass production of identical sections of the corridor-type buildings, such as hospitals or hotels, different types of tunnels. The installation of the tunnel formwork system is provided by a crane. However, different kinds of formwork systems of this type could be manufactured depending on the task needed.

One example of the Tunnel formwork system is a product by the company MESA. The name of this system is ERTF (shown in Figure 12). Tunnel Form is a system that allows casting of walls and slabs in one operation on a daily cycle. Construction durations are reduced significantly by this rapid system when compared to conventional methods. Tunnel Form System brings speed, quality and accuracy to the concrete construction and provides big savings in finishing. Hi-tech technologies for steel formwork production make tunnel forms strong and durable. The system creates efficient load-bearing structures which are known as the most earthquake resistant structures.

Similar to other modern systems, ERTF type also has an advantage over old formwork systems. Hi-tech all-steel system with 3 mm steel surface provides durability and strength. The service life of ERTF Tunnel Form system is good for 500 reuses as long as the system is used properly in accordance with instructions. The steel panel surface provides smooth concrete when it is finished. Together with the dimensional accuracy these features of the system eliminate finishing works like plastering. As safety is very important part of the construction process, Tunnel formwork system provides very high jobsite safety due to the full perimeter platform system.



Figure 12 ERTF Tunnel formwork system (<http://www.mesaimalat.com/en/ertf-modular-tunnel-form-system>)

3.1.4 Non-removable formwork blocks.

Non-removable formwork block system is used for the construction of low height buildings. The most popular material used in the production of non-removable formwork blocks is the polystyrene foam. The advantage of using such technology is that in the end blocks made of polystyrene foam become insulating parts of the wall structure. Thus a structure built with the use of this system does not require additional insulation. The explanation for this is easy. The structure is completed with the use of non-removable formwork blocks composed of several layers: reinforced concrete coated with insulation from both sides. In addition to this, it also has very good high sound insulation.

An example of non-removable formwork technology is a product (shown in Figure 13) called AMVIC ICF (ICF-insulating concrete formwork) made by the company AMVIC. AMVIC ICFs consist of 2 panels of high-density polystyrene panels 1200mm long, 400mm high, and 65mm wide, spaced apart by high-strength polypropylene webs. The forms provide a fully insulating, permanent shuttering system into which concrete is poured. The advantage of using AMVIC product is that it provides excellent sound insulation, fire safety, thermal mass and durability for the structural lifetime. Thermal insulation provided by using polystyrene material has a U-value between 0.24 W/m²K and 0.11 W/m²K and it can be easily achieved. Extreme lightness of the foam blocks provides easy usage in construction and there is no need for heavy equipment and safety benefits. Also the use of such technology reduces the amount of waste produced on the construction site. (What is AMVIC ICF)



Figure 13 AMVIC ICF blocks (<http://www.amvicbuild.com/about-amvic-icf.php>)

3.2 Reinforcement in concrete structures

Reinforcement is a set of elements connected together and when working with concrete it prevents reinforced concrete structures from stresses. An important element of the reinforcement is the rebar. It is used to carry tensile loads on the structure. The most common material used for reinforcement is steel, but non-steel reinforcement is also used in construction. (<http://en.wikipedia.org/wiki/Rebar>)

3.2.1 FRP Rebar

FRP is a fiber-reinforced polymer. The most common composite rebar reinforcement is made of glass or polymers. Traditional metal rebars have been used for many years in the reinforcement of concrete structures and they continue to be used nowadays, too. However, despite its prevalence, traditional metal rebars have typical disadvantages and all those disadvantages are just defects of the material of which these rebars were made. There are some main disadvantages of using steel. The first one is corrosion which can appear in moist places of the structure. The second disadvantage is the big weight of metal reinforcement used for construction of reinforced concrete structures. Another disadvantage is the electrical and high thermal conductivity.

However, compared to the metal reinforcement, FRP rebars (Figure 14) have many advantages and one of them is that they do not rust or corrode. This advantage gives options to use FRP rebars in such applications as swimming pools, canals, aquariums, offshore platforms and piers, because it is perfect for long term immersions. Another benefit of using such material in reinforcement is that it can resist different kinds of chemicals. For example road salts, deicing chemicals and chemicals which can be found in wastewater treatment plants, pipeline tanks, and pulp and paper mills are solid waste water. Immunity to such chemicals gives an opportunity for reliable construction of roads, bridges, parking structures, retaining walls and foundations.

Moreover, in most cases FRP rebars have a 1.5 or 2 times bigger tensile strength than metal rebars. It gives a good counter-weight to high-

compressive strength of concrete. Also, a further benefit is the light weight of the composite rebar, which is one-quarter of the weight of steel rebars. Thus, there is less need for heavy equipment and it is easy to install, so the use of composite rebars can save the time of construction.

Composite rebars are widely used abroad, including Japan where it is used for reinforcement of concrete structures which has requirements for a high seismic resistance or in places where areas of construction are environmentally sensitive and it is undesirable to move heavy equipment around. FRP is dielectric (non-conductive), so in structures built with the use of this kind of rebars lightning strikes and interfere with electrical devices can be avoided.

While using composite rebars the constructor can save money, because compared to metal rebars FRP rebars can be taken with less diameter. However, if composite rebars are more expensive than metal rebars, it still is more cost-effective to use FRP rebars, because the lifecycle costs of FRP rebars can be much less than the lifecycle cost of metal rebars due to their need for repair. (A hidden revolution frp rebar gains strength)

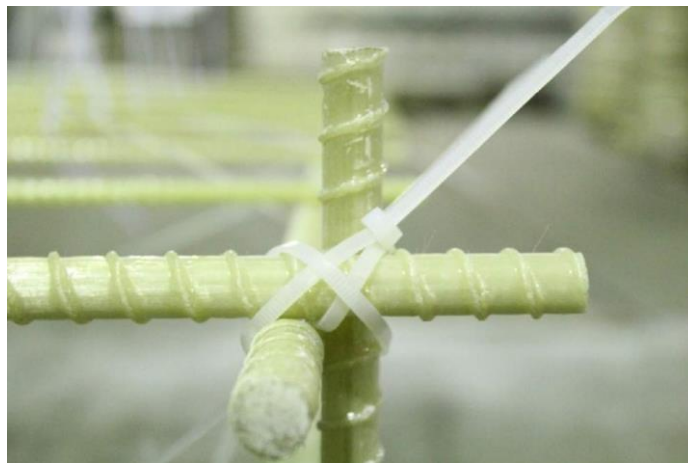


Figure 14 FRP rebars (<http://krasnodar.all.biz/stekloplastikovaya-kompozitnaya-armatura-g1975841#.VQq62-GgzIh>)

3.2.2 Rebar Couplers

Rebar Couplers are connection elements between two rebars with the same diameter, where at least one rebar can be freely rotated. An example of such a product is the technology of mechanical couplers system by the company called ERICO. The name of the system is LENTON mechanical coupler system. This technology represents a method of connecting reinforcement rebars by using specially designed rebar couplers. Within this system the connection of rebars is completed by using special LENTON couplers. Rebars with tapered thread on their ends are connected to the coupler with a similar tapered thread on its inside surface.

The adaptation of a mechanical coupler system technology to the construction site creates a strong connection over the entire length of reinforcement structure which provides a uniform distribution of stresses.

Thus, each individual LENTON coupler behaves as a continuous element of rebar.

LENTON mechanical coupler system technology includes different kinds of LENTON couplers (Figure 15), mechanical anchors with a different diameter (Figure 16), bar threading machine (Figure 17) and additional equipment such as a manual bar threading machine (Figure 18) and inspection wrench.



Figure 15 LENTON Couplers (<http://www.erico.com/catalog/literature/CP7J-WWEN.pdf>)



Figure 16 LENTON mechanical anchors (<http://www.erico.com/catalog/literature/CP7J-WWEN.pdf>)

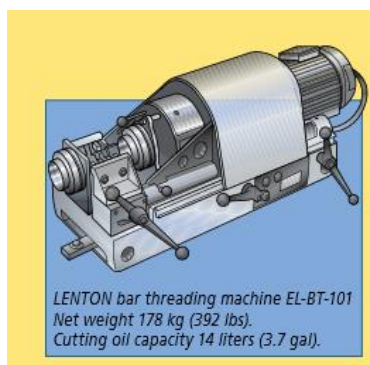


Figure 17 LENTON bar threading machine (<http://www.erico.com/catalog/literature/CP7J-WWEN.pdf>)



Figure 18 LENTON Manual bar threading machine
(<http://www.erico.com/catalog/literature/CP7J-WWEN.pdf>)

LENTON mechanical coupler system has a lot of different advantages compared to the traditional connection technologies for reinforcement. This method gives the opportunity to connect rebars with different diameters. Another advantage is the minimum increase of diameter of rebar in the connection point, which brings better consolidation of concrete in structure. Strong connections of such a system help to distribute stresses uniformly. Also, it improves steel-to-concrete ratio by eliminating half of the rebars necessary in the lap zone of the column.

The installation process is simple and has no special requirements for construction workers. To engage rebar on its place only few turns must be done. Such a method reduces the use of cranes on the site. LENTON bar threading machine can be easily located on the construction site because of its relatively small size and in addition to that it is easy to operate with. The threading process can be accelerated by using it in the fabrication shop. In cases when corrosion can increase the size of rebar and cause spall of concrete from the structure, integrity will be maintained, because LENTON couplers will perform as a continuous piece of rebar in lap splices.

All of these advantages can save money and time to the constructor by spending less time on installations and using less material in the building process. Also, the use of couplers will increase the life time of the reinforced concrete structure.

3.2.3 Continuous stirrup reinforcement system

Stirrups usually have rectangular shape steel parts of rebar cage, placed at regular intervals along a column or beam to prevent a shear failure. Continuous stirrup reinforcement (reinforcing spirals) is almost the same thing as traditional stirrups. The biggest difference is that the continuous stirrup reinforcement can be installed as one structure and traditional stirrups are installed separately from each other. In most cases this system can be applied for columns and beams.

Continuous stirrup (Figure 19) is made so that the vertical parts are located perpendicular to the supporting rebars of the reinforcement structure (or

rebar cage) and horizontal parts of the continuous stirrup are angled, defining a regular interval in between vertical parts.

The use of continuous reinforcing spirals can provide a significant cost-efficiency in the building process. Working with continuous stirrup reduces the amount of reinforcement approximately by 15% compared to the traditional stirrup system. Another advantage of such technology is that labor costs are smaller compared to the traditional stirrup system, because the installation process of rebar cage on the construction site with the use of spiral reinforcement is quicker compared to traditional stirrups.

The resistance of reinforcement structures built with the use of continuous stirrup is approximately 30% bigger than the resistance of reinforcement structures built with the use of separate stirrups. Also, spiral reinforcement gives exact accuracy in number of stirrups and intervals between them in the beam or column.

The continuous stirrup system is ecologically friendlier compared to the traditional stirrup system because less waste is produced during the installation. It is convenient and it keeps the construction site cleaner.

The spiral stirrups are transported to the construction site in the form of compact bundles. It can save product from extra damage during transportation and also save space due to its compactness. After transportation, the unpacked product can be installed to the supporting rebar and the mounting tape can be removed for the reinforcing spiral to take its default position. (<http://www.schnell.it/gallery/files/Spirex%20English.pdf>)



Figure 19 Continuous stirrup
(http://stroykonkurs.by/konkurs/news/2013/05/16/news_111.html)

3.2.4 Tube-confined concrete column system

The tube-confined concrete column system presented in Russia by IMET Group provides a new way of constructing reinforced columns. The tube-confined concrete column (shown in Figure 20) consists of an outer steel shell (metal pipe) that is filled with concrete, which forms the inner core. The entire system itself includes such materials as cement, sand for construction, rubble, gravel and metal. All of these materials can be easily purchased in Russia and around the world. Tube-confined concrete col-

umn system technology is effectively used in China. This technology can be applied for mass construction of high rise buildings, bridges, underground construction, and residential buildings.

This technology brings great advantages to the construction process because of its combined abilities of metal and concrete. Tube-confined concrete column technology has a high load capacity with a small cross-section of column. Another plus of using such a system in construction is that steel tubes perform as permanent formwork for concreting, providing both longitudinal and transverse reinforcement to the concrete. The concrete in the steel tube is under a uniform compression and in this state it forms the core with an increased carrying capacity. Compared to the traditional reinforced columns, tube-confined concrete columns allow to reduce the amount of metal and concrete used for the construction by 1,5-2 times, the weight of the structure by 2-3 times and labor costs by almost 2 times, because there is less work with reinforcement, welding and assembling of formwork. Also, the filling of steel pipe with concrete improves its anticorrosive resistance, by protecting the inner surface from corrosion and increasing the stiffness of the elements. In addition, it significantly increases the fire resistance of the structure.

As a result, it is a great product with a light weight, high strength and carrying capacity, excellent durability, plasticity and big fire resistance. The tube-confined concrete column system is easy to install because of less work with welding, no extra reinforcement and steel pipe works as a permanent formwork. Also, less material is used for the construction. In the end, all of these factors can save money and time to the constructor and improve the quality of the end product.



Figure 20 Tube-confined concrete column (http://imet-group.com/?page_id=388)

4 RESEARCH SURVEY

The main goal of the research survey is to compare traditional technologies with innovative technologies based on experience of specialists from different companies. The advantage of using modern ideas and techniques will bring more effectiveness to the construction site. To compare two sides of construction - old and new ways of building the main criteria are money and time. As an example for each comparison a concrete structure built with certain technology will be taken. Costs of transportation, cost of products, cost of using heavy machines, time of assembling and produc-

tion and approximate time used for all of the process will be compared. Prices are average, because they are compared between different companies. People were interviewed about the product they are working with (engineers in most cases). Most of comparison will be made based on their experience. Each technology also can have different criteria for comparison, depending on their difference. (Andrey interview 15th March 2015; Mihail interview 17th March 2015; Sergey interview 17th March 2015)

4.1 Frame formwork system

In this case for comparison will be made of the frame formwork PERI TRIO. The formwork is more comfortable and mostly used for monolithic construction of walls, columns, foundations and other building parts.

The structural element taken for this case is a rectangle shape with the sides of 4 meters and 5 meters, the height is 2.8 meters and thickness 300 mm. The main categories for comparison between the traditional formwork made mostly of plywood and frame formwork PERI TRIO will be transportation, rent and price of formwork, labor costs and speed of construction, heavy machines used on site.

For transportation of parts for frame formwork PERI TRIO a truck is used in most cases which can carry 20 tons (Figure 21) and it costs 6000 rubles. Parts for the traditional formwork, such as wooden beams and plywood with the size of 1220*2440*15 mm can be transported by a small platform transporter GAZ (Figure 22) which can carry 3-4.3 tons and it costs 3000-4000 rubles. On a bigger scale transportation of materials for traditional formwork can cost more due to the fact that the traditional formwork can be used almost ten times less than the frame formwork, because of pure quality of its material.



Figure 21 Truck with the size of 20 tons (<http://buzzerg.com/139705-daf-xf-truck-id-75059.htm>)



Figure 22 Platform transporter GAZ (<http://survincity.com/2013/04/the-first-test-drive-the-new-gazelle-next/>)

Labour costs can be calculated taking into account the speed of assembling of formworks and cost for normal eight hours working day per person. The average price of one worker is 1000 rubles per one day. For that a team of workers consisting of 8 people will be taken. Such a team can complete 250-300 m² of frame formwork PERI TRIO. For element given in the example amount of square meters for formwork will be equal to 97.5 m².

Area of formwork
$2.8m(10m + 8m) + 2.8m(9.4m + 7.4m) = 97.44m^2$

Price for renting the frame formwork PERI TRIO is 700 rub/m² per month. With easy calculations it can be found that the rental cost for PERI TRIO will be 3412.5 rubles per day. The speed of assembling of modern formwork with 8 workers team will be 3.12 hours and there will still be time for pouring concrete into the formwork on the same day. After concrete is dried out the formwork can be taken away and used again.

Rental cost for PERI TRIO per day
$\frac{700 \cdot 97.5}{20} = 3412.5 \frac{\text{rub}}{\text{day}}$
Assembling speed of PERI TRIO
$\frac{97.5m^2}{250m^2} \cdot 8h = 3.12h$

The assembling speed of the traditional formwork with the same team of 8 workers will be 70-100 m² per 8 hours working day. By taking the average speed of assembling the traditional formwork and doing short calculations the amount of time spent on making the formwork can be found. It is one working day or even more. Plywood used for construction of traditional formwork can be used around 20 times which is around 10 times less than PERI TRIO formwork can be used.

Assembling speed of traditional formwork
$\frac{97.5m^2}{85m^2} \cdot 8h = 9.176h$

The price for the traditional formwork can be calculated from the price of birch plywood used and price of wooden beams used as supports. The price for plywood sheet with the dimensions of 1525*1525*18 mm is 850 rubles and the price for supporting aspen beams with the dimensions of 50*150 mm is 4450 rub/m³. For one support made of aspen beams needed 0.0248 m³ of material, which will cost 110 rubles. For this particular case the traditional formwork will consist of 14 supports. It will cost 1540 rubles. For vertical parts of formwork made of plywood will be needed 42 pieces. One time use will cost 1785 rubles. The sum of prices for both materials for one time use of traditional formwork is 3325 rubles.

Cost of supports for traditional formwork	
$(1.3 + 1 + 1) \cdot 0.050.15445014 = 1541.925$ rub	
Amount of plywood sheets needed	
$\frac{97.5}{1.5351.535}$	= 41.38
Cost of one time use of plywood for traditional formwork	
$\frac{42 \cdot 850}{20}$	= 1785 rub

Of the heavy machines in this particular case will be used a crane which can carry 16 tons. Price for one day of using this crane will cost 8000 rubles. On a bigger scale for PERI TRIO such a crane will be needed to move heavy parts of formwork from one place to another. In case with the traditional formwork crane will be used less to move materials. However, in both cases crane can be used.

As a conclusion it can be clearly seen in Table 5 that using the frame formwork in mass monolithic construction will save time of works, labour cost and money for materials and even transportation.

Table 5. Comparison

Traditional formwork	PERI TRIO formwork
Transportation	
4000 rub. *	6000 rub. *
*Notice that this kind of formwork may require more transportation due to its pure quality	*Notice that this kind of formwork need less transportation due to its long usability and good quality.
Assembling speed	
9.2 hours	3.1 hours
Cost	
1785 rub.*	3412.5 rub.*
*Notice that this is price only for one time use of such formwork.	*Notice that formwork can be used not once a day.

4.2 Beam formwork system

In this chapter will be discussed beam formwork system PERI VARIO by PERI Company. This formwork is more comfortable and mostly used for the construction of columns, walls, bridges, supporting elements.

The structural element chosen for this particular case is a rectangular-shaped element with the sides of 6 meters and 5 meters, height of 2.8 meters and thickness 200 mm. The main categories for comparison of traditional formwork and beam formwork PERI VARIO will be transportation, rent and price of formwork, labor costs, speed of construction and heavy machines used on site.

The transportation of beam formwork system PERI VARIO is similar to the transportation method of frame formwork PERI TRIO. In most cases for its transportation used a truck which can carry 20 tons (Figure 21) and it costs 6000 rubles. As in the previous example the parts for traditional formwork, such as wooden beams and plywood with the size of 1220*2440*15 mm can be transported by a small platform transporter GAZelle (Figure 22) which can carry 3-4.3 tons and it costs 3000-4000 rubles. For a bigger scale transportation of materials the traditional formwork can cost more due to the fact that the material for the traditional formwork will spoil faster and it can be used almost ten times less than the beam formwork PERI VARIO.

Labor costs for this particular case can be calculated from summing up the money paid to the construction employee for eight hours per day and money paid for the rent of the formwork or for the price of materials it is assembled from. As written in the previous comparison the money paid to one employee on a construction site is 1000 rubles per one working day. For this comparison team of six people is taken. Such a team can complete 210-240 m² of beam formwork PERI VARIO for one 8 hours working day, depending on the difficulty of elements that need to be assembled. For completing this particular example 120.96 m² of formwork will be needed.

Area of formwork
$2.8 \times (12\text{m} + 10\text{m}) + 2.8 \times (11.6\text{m} + 9.6\text{m}) = 120.96\text{m}^2$

The renting price of the beam formwork PERI VARIO is 800rub/m² per month. There are 20 working days in one month. If taking this price into account and calculating the price of one day of using such formwork it will be 4838.4 rubles. From simple calculations shown below it can be seen that a team of six construction workers can assemble for 4.399 hours and there will be still time for pouring concrete in to formwork.

Rental cost of PERI VARIO per day
$\frac{800 \times 120.96}{20} = 4838.4 \frac{\text{rub}}{\text{day}}$
Assembling speed of PERI VARIO formwork

$$\frac{120.96 \text{ m}^2}{220 \text{ m}^2} \cdot 8 \text{ h} = 4.399 \text{ h}$$

As in the previous example with the same team of 6 people can be assembled one 70-100 m² per 8 hours working day, depending on the location and place where the formwork should be assembled. Having an average speed of constructing the traditional formwork and doing simple calculations the amount of time spent for making the formwork can be found and it is 11.38 hours, which is almost three times more than having the beam formwork. So it means that using the traditional formwork requires two days payment for construction workers, which is twice bigger than in the case of using the beam formwork PERI VARIO.

Assembling speed of traditional formwork
$\frac{120.96 \text{ m}^2}{85 \text{ m}^2} \cdot 8 = 11.384 \text{ h}$

Calculating the price for the traditional formwork is similar to the previous case. These simple calculations require the price of birch plywood and price of supporting aspen beams. The price for birch plywood sheet with the dimensions of 1525*1525*18 mm is 850 rubles and price for supporting aspen beams with dimensions of 50*150 mm is 4450 rub/m³. For one support made of aspen beams 0.0248 m³ of material needed, which will cost 110 rubles. For this particular case the traditional formwork will consist of 16-18 supports. It will cost 1870 rubles. For vertical parts of the formwork made of plywood 52 pieces will be needed. One time use will cost 2210 rubles. The sum of prices for both materials for one time use of the traditional formwork is 4080 rubles.

Cost of supports for traditional formwork
$(1.3 + 1 + 1) \cdot 0.05015445017 = 1872.338 \text{ rub}$
Amount of plywood sheets needed
$\frac{120.96 \text{ m}^2}{1.535 \text{ m} \cdot 1.535 \text{ m}} = 51.336$
Cost of one time use of plywood for traditional formwork
$\frac{52 \cdot 850}{20} = 2210 \text{ rub}$

In this case to build the formwork for an element crane which can carry 16 tons is needed to move the parts on the construction site to the place of formwork assembling. Having a crane on the construction site costs 8000 rubles per day. For this particular case comparing to beam formwork PERI VARIO it is possible that the traditional formwork will require a crane for two days, which can double the price.

Taking into the account all of the facts written above it can be seen from Table 6 that when using the beam formwork gives almost the same result as when using the frame formwork, which means that both of them are

very useful, but should be used depending on the application, project and location where such formworks should be applied.

Table 2. Comparison

Traditional formwork	PERI VARIO formwork
Transportation	
4000 rub. *	6000 rub. *
*Notice that this kind of formwork may require more transportation due to its pure quality	*Notice that this kind of formwork needs less transportation due to its long usability and good quality.
Assembling speed	
11 hours	4 hours
Cost	
2210 rub.*	4838 rub.*
*Notice that this is price only for one time use of such formwork.	*Notice that formwork can be used not once a day.

4.3 Tunnel formwork

For this case of comparison between the new and old technology is chosen MESA tunnel formwork and the traditional formwork. Using the modern tunnel formwork by MESA it is most comfortable to construct buildings with similar structure, such as hospitals, schools or other project which consist a lot of similarity in it.

The structure of the rectangular element taken for the comparison is similar to the previous example, but the main difference is that in this case the structure includes not just vertical elements, but also horizontal (ceiling). The dimensions of taken rectangular shape element are 3 meters and 4 meters, height 2.8 meters and thickness is 200 mm. The main categories for comparison of this case are transportation, rent and price of formwork, labor costs and speed of construction, heavy machines used on construction site.

The transportation costs can be seen from the examples above as the tunnel formwork system by MESA transported by a truck (Figure 21), which can carry up to 20 tons and costs 6000 rubles. For the traditional formwork system GAZelle car is used which can carry 3-4 tons and it costs 3000-4000 rubles. However, the modern formwork system is more advantageous in terms of the transportation.

Labor costs are calculated in the same way as in the example shown in comparison for PERI VARIO beam formwork. In this case a team of eight construction workers is taken. Such team can complete assembling of

around 300 m² of chosen modern formwork for eight hours working day, depending on the project.

Area of formwork
$2.8m(8m + 6m) + 2.8m(7.6m + 5.6m) + 3m \cdot 4m + 2.6m \cdot 3.6m = 97.52m^2$

For completing the particular element chosen in this example the rental price for MESA tunnel formwork is 900rub/m² per month. It can be seen that from simple calculations, which are similar to the previous case the price for one day of using the modern formwork is 4388.4 rubles. The assembling speed can be found in the calculations below and it is 2.6 hours.

Rental cost of MESA tunnel formwork
$\frac{900 \cdot 97.52}{20} = 4.388 \times 10^3$ rub
Assembling speed of MESA Tunnel formwork
$\frac{97.52}{300} \cdot 8 = 2.601$ h

The traditional formwork which is taken for comparison in this particular case is the same as in the case with PERI TRIO. With this information the speed of assembling for traditional formwork for constructing of chosen element can be calculated. It is 8.66 hours. Also, the costs for materials needed are 1650 rubles for 15 supports and 1785 rubles for one use of birch plywood. The sum of this two gives 3435 rubles in general, which is smaller than using the tunnel formwork. However, in the long term perspective MESA tunnel formwork costs less, because of it great durability comparing to the traditional formwork.

Assembling speed of traditional formwork
$\frac{97.52}{90} \cdot 8 = 8.668$ h
Cost of supports for traditional formwork
$110 \cdot 15 = 1.65 \times 10^3$ rub
Number of plywood sheets needed
$\frac{97.52m^2}{1.535m \cdot 1.535m} = 41.388$
Cost of one time use of plywood for traditional formwork
$\frac{42 \cdot 850}{20} = 1.785 \times 10^3$ rub

The situation with using a crane on the construction site for moving parts for the traditional and modern formwork are the same as in two previous cases. From that and other factors written above it can be concluded that such formwork is more profitable for the constructor then the option with the traditional formwork. Comparisons are shown below in Table 7.

Table 7. Comparison

Traditional formwork	MESA tunnel formwork
----------------------	----------------------

Transportation	
4000 rub. *	6000 rub. *
*Notice that this kind of formwork may require more transportation due to its pure quality	*Notice that this kind of formwork need lees transportation due to its long usability and good quality.
Assembling speed	
8.5 hours	2.5 hours
Cost	
1785 rub.*	4388 rub.*
*Notice that this is price only for one time use of such formwork.	*Notice that formwork can be used not once a day.

4.4 Non-Removable formwork

There are different cases of a non-removable formwork, which is the most comfortable for the construction of low height buildings with one, two or three floors.

Non-removable formwork by the company “Tehnoblok” is taken for this comparison is taken non-removable formwork by company “Tehnoblok” (Figure 23). The thickness of such formwork is 23 centimeters or more, depending on the chosen type, because the thickness of insulation can vary. For a traditional formwork is taken a wall with a thickness of 42 centimeters, where 150 mm is a concrete layer, 150 mm insulation and brick facade with a thickness of 120 mm. The element chosen for comparison is a wall with a height of 2.8 meters and the length of 4 metersd. On the picture below you can see: 1-façade (material can be chosen), 2-insulation (foam), 3-fixing bolts M10, 4-brackets, 5-ties, 6-part of the formwork.

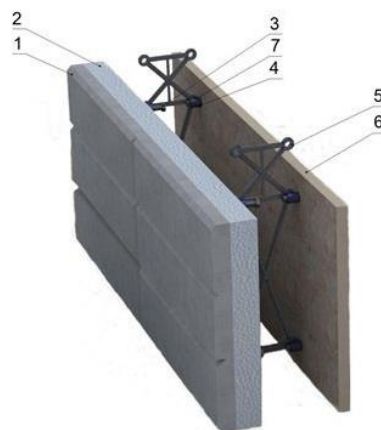


Figure 23 Non-Removable formwork “Tehnoblok”. (<http://tehnoblok.pro/nesemnaya-opalubka>)

The main categories for comparison are the transportation, labor costs and use of heavy machines on the construction site.

For the transportation of both technologies the same car can be applied. GAZelle is good for both cases. The non-removable formwork is light-weight and does not require truck for transportation. Materials for the traditional formwork can be transported with the same GAZelle car as in the case with the non-removable formwork, because materials are not very heavy. In both cases a bigger car will be needed, depending on the amount of materials needed for the construction.

The labor costs for a non-removable formwork “Tehnoblok” can be calculated from having the information about speed of assembling of the formwork and number of people working on it. For this particular case a team of two construction workers is taken. Such a team can do 0.4 m of the given wall for one day including pouring the concrete into the structure. The wall is 2.8 m height, what gives us result of 7 days time and the wall done with the use of non-removable formwork “Tehnoblok” is ready. The main difference of construction with the non-removable formwork is that it consists of only two steps, - assembling raw of formwork and pouring the concrete into the structure (if not including reinforcement). The price for a piece of wall with the dimensions (23*1000*400mm) constructed using non-removable formwork “Tehnoblok” is 1600 rubles. A simple calculation below gives the price of such a wall (not including concrete) and it is 44800 rubles.

Cost of chosen element with use of non-removable formwork
$1600 \cdot 7 = 4.48 \times 10^4 \text{ rub}$

The labor costs for completing the task with the traditional formwork can be calculated with same information as in the case of the non-removable formwork, but in this case the construction of a particular element will take more steps. In addition, the number of workers needed is twice more. First, the formwork should be assembled to construct the concrete part of the wall; second is pouring concrete; third, taking formwork of after concrete is dry and only then installing insulation and façade material. From the information given in previous cases, the price of the traditional formwork used for this case can be calculated. Assembling speed with such a team will be 40-60 m² of formwork per day, the area of formwork needed is 23.24 m². Further, speed of assembling of such formwork can be calculated. It is 3.7 hours. If taking into account the time of pouring the concrete, time needed for concrete to dry out and disassembling formwork it can take from 2-4 days.

Area of formwork needed
$4 \cdot 2.82 + 2.80 \cdot 152 = 23.24 \text{ m}^2$
Speed of assembling
$\frac{23.24 \text{ m}^2}{50 \text{ m}^2} \cdot 8 \times 3.7$ h

The price for a birch plywood sheet with the dimensions of 1525*1525*18 mm is 850 rubles and the price for supporting aspen beams with the dimensions of 50*150 mm is 4450 rub/m³. For one support made of aspen beams needed cost 110 rubles. For this particular case the traditional formwork will consist of 8 supports and 10 pieces of birch plywood. It will cost 8500 rubles.

Cost of supports needed
$110 \times 8 = 880 \text{ rub}$
Amount of plywood needed
$\frac{23.24 \text{ m}^2}{1.535 \text{ m} \times 1.535 \text{ m}} = 9.863$
Cost of formwork
$10 \times 850 = 8.5 \times 10^3 \text{ rub}$

The average price for insulation (foam) is 1400 rub/m³. The volume of insulation needed is 1.63 m³ which gives us the cost of 2352 rubles for a wall taken in this case. The average price for brick is 2600 rub/m³. The volume of brick needed is 1.34 m³ which gives us the cost of 3484 rubles for a wall taken in this case. The speed of assembling insulation for this particular case wouldn't take more than half of the day. The assembling speed of brick with team of four people will be five square meters per day. The area of brick facade is 11.2 m². With such an area it can be clearly seen that facade will be completed for a bit more than a day.

Insulation needed
$4 \text{ m} \times 2.8 \text{ m} \times 0.15 \text{ m} = 1.68 \text{ m}^3$
Cost of insulation needed
$1.68 \times 1400 = 2.352 \times 10^3 \text{ rub}$
Volume of bricks needed
$4 \times 2.8 \times 0.12 = 1.344 \text{ m}^3$
Cost of brick needed
$1.34 \times 2600 = 3.484 \times 10^3 \text{ rub}$

From the information above it can be seen that the speed of construction is bigger in case of the traditional system, but if you take the money spent on the materials into account the traditional formwork is more advantageous compared to the modern system. Even if taking into account that in the case of the traditional formwork will be needed a crane and machine for pouring the concrete. Thus can cost 14000 rubles per day, while in the case of the modern non-removable formwork only a simple concrete mixer (Figure 24) is needed and its cost is 10000 rubles, the traditional formwork will still be cheaper to use in this particular case. The comparison can be seen from table 8.



Figure 24 Concrete mixer

Table 4. Comparison

Traditional formwork	Tehnoblok
Transportation	
4000 rub.	4000 rub.
Assembling speed	
19 hours*	4.5 hours
*Notice that additional work is also taken into account to complete the structure using this kind of formwork.	
Cost	
15000 rub.*	44800 rub.
*Notice that this is price contains also additional prices to complete the structure using such formwork	

5 APPLICATION

This chapter contains an example of a framework design for a multi-storey residential building located in Saint-Petersburg. The wall plan (Figure 25) used for framework preparations is presented below. The height of the concrete cast in this case is 2.65 m.

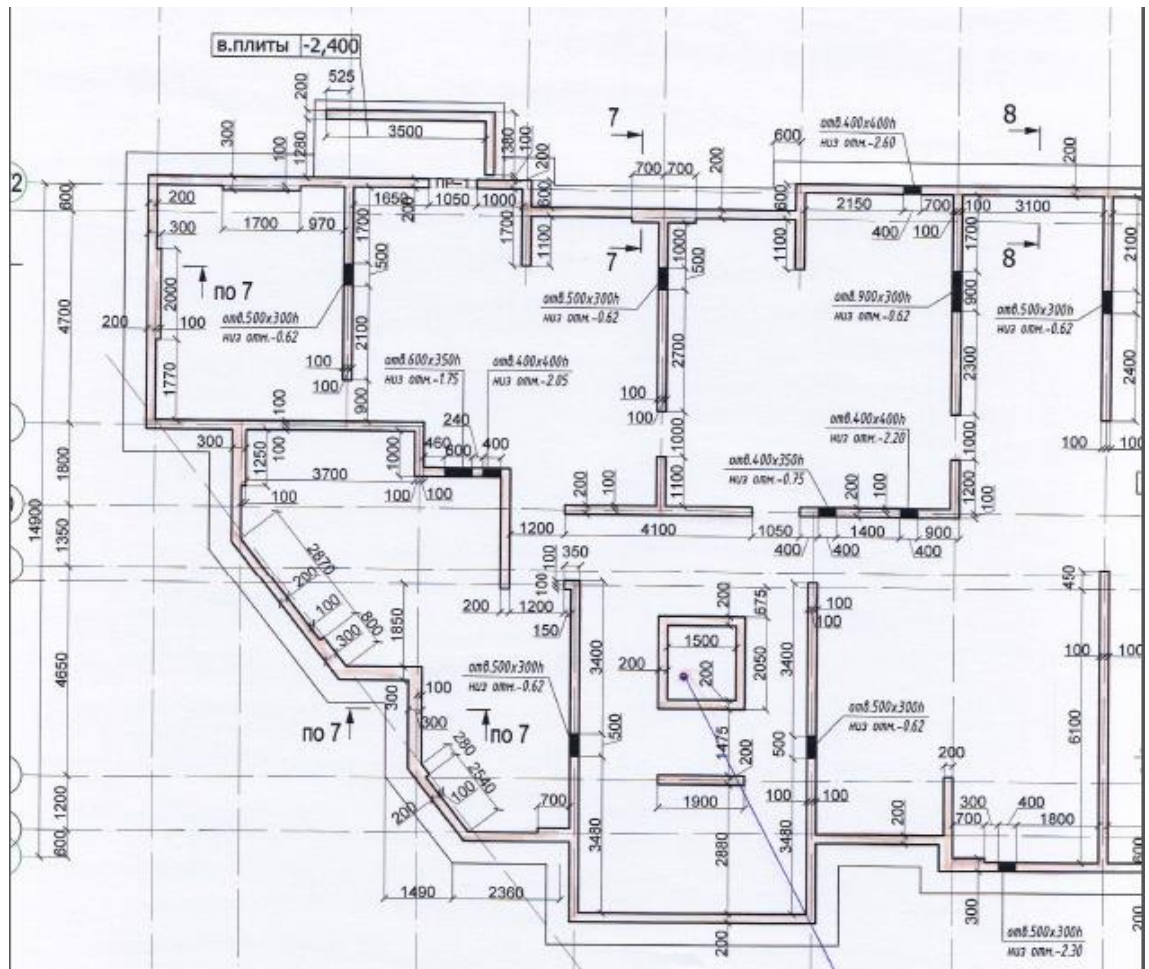


Figure 25 Wall Plan

The framework analysis is performed in several steps. The customer sends the wall plan to the framework manufacturing company. After that the AutoCAD drawing (Figure 26) is produced containing the framework plan that covers all the walls shown in the above drawing. As a result the following is acquired. The formwork is developed and manufactured by company the “Tehnokom-BM”. The official distributor is “Him-StroySnab” company.

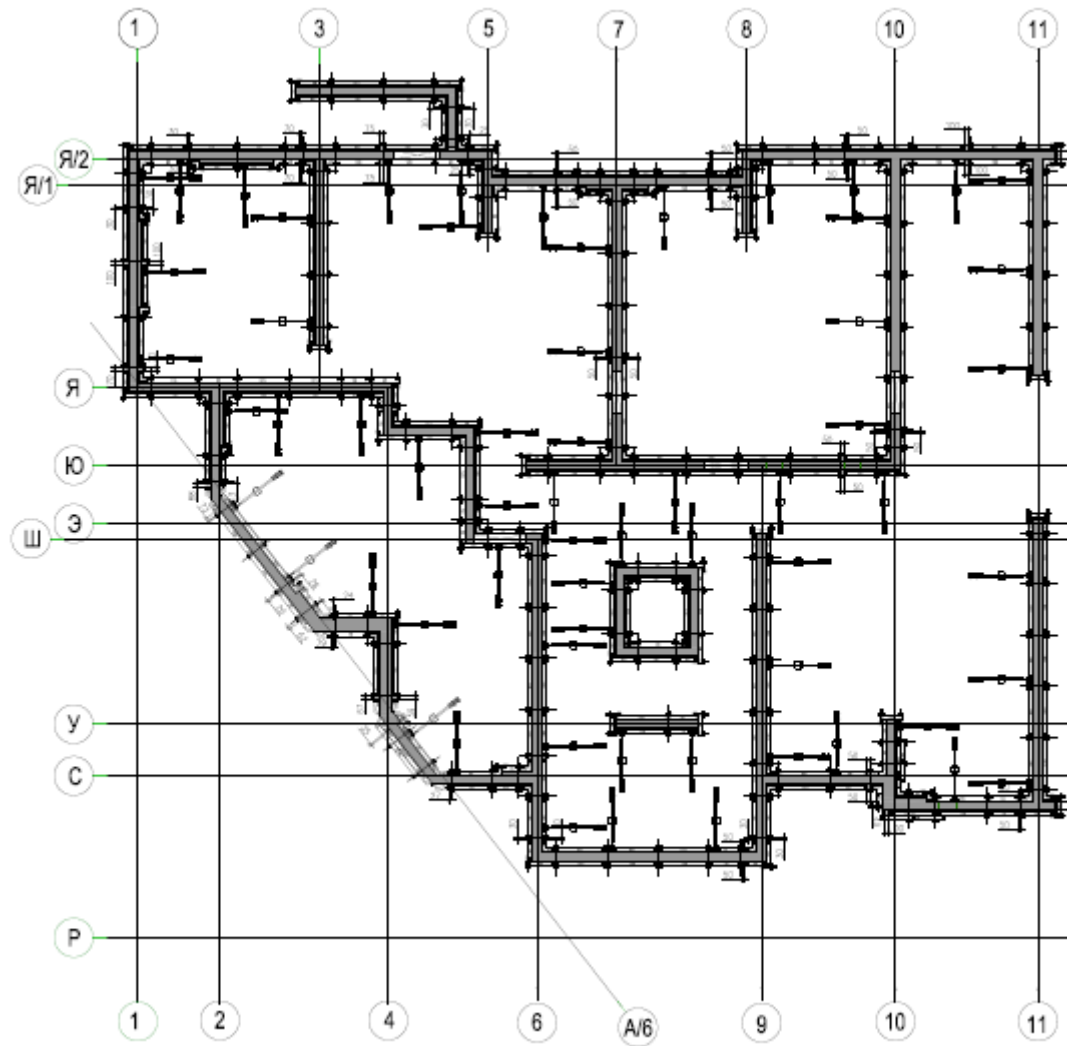


Figure 26 AutoCAD drawing.

When the framework plan is ready the AutoCAD schedule tables are applied to calculate the necessary number of formwork panels (Figure 27) and supports. The picture of a formwork panel is shown in the pictures below. Panels used are Gamma formwork panels, which are similar to PERI formwork panels.



Figure 27 Gamma formwork Panel

The next picture demonstrates the placement of supports for each panel (Figure 28).

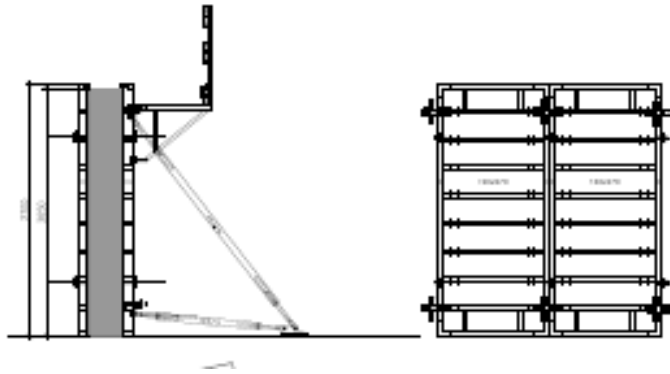



Figure 28 Placement of supports

All the panels are transported through the building using a lifting crane. The number of panels and corresponding details are summarized in a bill of quantities (Table 9) that contains information on the total cost, total mass and name of products.

Table 9. Bill of quantities

Company: HimStroySnab				
Project: Monolitich building according to the drawings				
	Specifications			
Serial number	Name of element	Amount (units)	Cost of unit (rub.)	General costs, rub. (including taxes-18%)
1.0.0	Frame formwork "Gamma Kaskad"			
	Hight 3,0 m., Area - 842 sq.m.			
508952	inside angle "Gamma KASKAD" 0,25x0,25x3,0	11	7 838,70	86 225,70
508957	inside angle "Gamma KASKAD" 0,30x0,20x3,0 left	2	7 838,70	15 677,40
508967	inside angle "Gamma KASKAD" 0,30x0,20x3,0 right	2	7 838,70	15 677,40
508951	inside angle "Gamma KASKAD" 0,30x0,30x3,0	32	7 933,31	253 865,92
508958	inside angle "Gamma KASKAD" 0,30x0,35x3,0 left	2	8 200,00	16 400,00
508960	inside angle "Gamma KASKAD" 0,30x0,40x3,0 left	1	8 300,00	8 300,00
508964	inside angle "Gamma KASKAD" 0,30x0,50x3,0 left	2	8 397,32	16 794,64
513753	angle "Gamma" 0,30x0,30x3,0	4	34 494,54	137 978,16
509410	Hinged panel "Gamma KASKAD" 0,30x0,30x3,0	5	9 685,75	48 428,75
509414	Hinged panel "Gamma KASKAD" 0,40x0,40x3,0	3	10 845,80	32 537,40
508060	Formwork panel "Gamma KASKAD" 0,30x3,0	2	6 217,00	12 434,00
508063	Formwork panel "Gamma KASKAD" 0,35x3,0	6	6 835,21	41 011,26
508066	Formwork panel "Gamma KASKAD" 0,40x3,0	10	7 015,50	70 155,00
508076	Formwork panel "Gamma KASKAD" 0,50x3,0	36	7 555,16	271 985,76
508080	Formwork panel "Gamma KASKAD" 0,55x3,0	4	8 126,62	32 506,48
508085	Formwork panel "Gamma KASKAD" 0,60x3,0	3	8 156,64	24 469,92
508088	Formwork panel "Gamma KASKAD" 0,65x3,0	22	8 300,28	182 606,16

508091	Formwork panel "Gamma KASKAD" 0,70x3,0	10	8 502,10	85 021,00
508094	Formwork panel "Gamma KASKAD" 0,75x3,0	8	8 858,47	70 867,76
508099	Formwork panel "Gamma KASKAD" 0,80x3,0	16	9 214,85	147 437,60
508102	Formwork panel "Gamma KASKAD" 0,85x3,0	10	9 424,60	94 246,00
508105	Formwork panel "Gamma KASKAD" 0,90x3,0	6	9 978,51	59 871,06
508108	Formwork panel "Gamma KASKAD" 0,95x3,0	10	10 301,28	103 012,80
508111	Formwork panel "Gamma KASKAD" 1,00x3,0	2	10 589,44	21 178,88
508114	Formwork panel "Gamma KASKAD" 1,05x3,0	6	11 180,00	67 080,00
508116	Formwork panel "Gamma KASKAD" 1,10x3,0	12	11 414,19	136 970,28
508120	Formwork panel "Gamma KASKAD" 1,15x3,0	2	11 612,74	23 225,48
508121	Formwork panel "Gamma KASKAD" 1,20x3,0	103	11 811,29	1 216 562,87
508515	Universal formwork panel "Gamma KASKAD" 0,80x3,0	1	11 400,00	11 400,00
508522	Universal formwork panel "Gamma KASKAD" 1,10x3,0	1	13 513,54	13 513,54
508523	Universal formwork panel "Gamma KASKAD" 1,20x3,0	1	14 321,40	14 321,40
513901	Hinged formwork panel "Gamma" 0,10x0,10x3,0	1	6 700,00	6 700,00
501001	Universal zinced coupler "Gamma"	570	950,00	541 500,00
501003	Bolt, SAS 15 FC Germany(2013)	280	148,80	41 664,00
501004	Nut zin. d=90 мм "Gamma"	780	115,00	89 700,00
501006	Front anchor "Gamma"	220	249,22	54 828,40
501008	bracket scaffolds "Gamma"	60	1 108,73	66 523,80
501009	duplex support "Gamma"	60	3 100,00	186 000,00
501012	Crane attachments "Gamma"	2	4 000,00	8 000,00
501026	Strombek "Gamma" 1000MM	2	985,53	1 971,06
501032	Strombek "Gamma" 1500MM	4	1 144,73	4 578,92
501051	Plug element "Gamma"	3000	2,20	6 600,00
				4 339 828,80
		Sum:	4 339 828,80	rub.
		TAX 18%:	662 007,78	rub.
		Mass:	49 086,47	kg.

5.1 RATU

5.1.1 Production Data and Quantities

Labor costs and time for completing the task can be calculated according to Finnish production data Ratu. It is given as an application, depending on how many people you have. To complete this task several steps should be taken. Each step includes different type of works. In this particular project the task is to complete monolithic concrete walls using a frame the

formwork Gamma (which is the Russian analog of PERI formwork). For walls used frame formwork “Gamma KASKAD”.

Ratu Production Data book presents the following steps for frame formwork works:

- Clearing
- Formwork
- Reinforcement
- Concreting
- Completing of monolithic screed
- Installations of prefabricated concrete structures
- Initial leveling of concrete surfaces
- Polishing and filling of irregularities

For the project given as an application not all steps are needed. By going through all of the steps each is taken separately and time for the needed work to complete the task is calculated according to the information given for the project. The process of completing only one floor is taken as an example to draw up a schedule.

The first important step for calculations is completing formwork works. Initially base works before completing formwork are done and accepted, necessary machines and equipment are on site ready to start. According to Ratu production data for the scope of work for the walls of one floor is the following: speed of assembling, disassembling and cleaning. The speed of assembling and disassembling (and cleaning) is 0.27 ph/m². Also, in calculations the factor TL3 should be taken, which depends on amount of square meters that must be assembled. This factor adds more accuracy to the calculations. For this case 842 m² of frame formwork should be assembled, which is between 500 and 1000 m². In the table of Ratu production book for formwork work can be seen that the factor is between 1.05 and 1.1. The pictures with Ratu tables shown below give information needed for the calculations.

Трудозатраты ТЗ на объекте нового строительства

Дощатая опалубка	чч/м ² опалубки
Роствержи	
- монтаж опалубки	0,43
- распалубка и очистка	0,35
Стены	
- монтаж	0,29
- распалубка и очистка	0,32
Щитовая опалубка	
Стены	
- монтаж	0,27
- распалубка и очистка	0,27
Плиты	
- монтаж	0,28
- распалубка и очистка	0,30
Лифтовые шахты, лестничные клетки	
- монтаж	0,40
- распалубка и очистка	0,32
Кассетная опалубка	
Стены	
- изготовление, монтаж	0,37
- распалубка и очистка	0,12
Колонны	
- изготовление, монтаж	0,90
- распалубка и очистка	0,27
Плиты	
- монтаж	0,21
- распалубка и очистка	0,16
Балки	
- монтаж	0,35
- распалубка и очистка	0,20
Разборно-переставная опалубка	0,09
Фигурная разборно-переставная опалубка	0,15
Столбовая опалубка	
- монтаж	0,13
- распалубка и очистка	0,02
Купольная опалубка	
- монтаж	0,31
- распалубка и очистка	0,19
Угловая опалубка	
-монтаж, распалубка, очистка	0,15

Speed of assembling and disassembling

На объекте нового строительства на трудозатраты влияют

Объем опалубочных работ, м ²					
Дощатая и щитовая опалубка	-	100	200	400	800
Кассетная и опалубка на столах	500	1000	2000	4000	8000
Кассетная опалубка, колонны и балки	125	250	500	1000	2000
Разборно-переставная и фигурная разборно-переставная опалубка	1000	-	2000	-	4000
Купольная опалубка	250	500	1000	2000	4000
Угловая опалубка	300	-	-	400	-

коэффициент 1,20 1,10 1,05 1,00 0,95 0,90 TL3 factor depending on amount or form

Formwork for walls
$\frac{ph}{m^2}$
$0.27 + 0.27 = 0.54 \text{ m}^2$
$0.54842 = 454.68 \text{ ph}$
$1.075454.68 = 488.781 \text{ ph}$
$\frac{ph}{shift}$
$108 = 80 \text{ shift}$

$$\frac{488.781}{80} = 6.11 \text{ shift}$$

On the construction site there are two teams of five people each. From making simple calculations which are presented above can be seen that the team of 10 people can complete this step of task for a bit more than 6 working days.

The next important step to complete is reinforcement. Initially reinforcement located on the site in bundles and sorted by diameter, formworks are assembled, and all needed equipment and drawings are ready. The scope of works that have to be done is the following: transportation of materials from place to place, cutting, bending and installation of reinforcement, cleaning site and packing of equipment. The speed of transporting reinforcement, cleaning site after work and packing equipment is in between 0.1 and 3 ph/1000kg, cutting and bending is in between 2.4 and 3.3 ph/1000kg and installation of reinforcement with a width of 8 mm for walls is 13 ph/1000kg. In presented project 19126 kg of reinforcement is used. The correction factor TL3 for this particular case is very much close to one. All information is taken from tables of Ratu production data which are shown below.

Трудозатраты ТЗ на объекте нового строительства

Подготовительные работы	чч/1000кг	Transporting reinforcement, cleaning site after work and packing equipment; cutting and bending
- перемещения материалов и пр.	0,10... 3,00	
Механизированная резка и отгиб арматуры	2,40...3,30	

Армирование

Ростверки, стержень

-10 мм	8,50
-12 мм	6,30
-16 мм	5,00

Плита, сетка 10 м²

-4 мм, 150 мм	16,50
-6 мм, 150 мм	7,50
-8 мм, 150 мм	5,00

Плита, стержень

-8 мм	12,00
-10 мм	8,00
-12 мм	5,50
-16 мм	4,50

Стены, стержень

-8 мм	13,00	installation of reinforcement
-10 мм	7,30	

Лифтовая шахта, стержень

-8 мм	12,00
-10 мм	10,00

Убежище для населения, стержень

-10 мм	8,50
-12 мм	6,30
-16 мм	5,00

Балки, стержень

-10 мм	12,00
-12 мм	10,00
-16 мм	9,50

Колонны, стержень

-12 мм	10,00
-16 мм	9,80
-20 мм	9,50

На объекте нового строительства на трудозатраты влияют

Общий объем армирования, 1000 кг

Ростверки	5	7	12	25	50
Стены	5	10	20	40	80
Плиты	25	50	75	150	300
Колонны, балки	5	7	12	25	50

коэффициент	1,10	1,05	1,00	0,95	0,90	TL3 factor
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Reinforcement	
$\frac{ph}{2 + 2.85 + 13 = 17.85}$	1000kg
$17.8519126 = 3.414 \times 10^5$	ph
$341.41 = 341.4$	ph
$\frac{341.4}{80} = 4.268$	shift

By making calculations which can be seen from above according to given information can be seen that reinforcement step can be completed for a bit more than four days by the same team of workers.

The third and very important step for the given project is concreting. The amount of concrete to be filled is 218.5 m³. Initially formwork and reinforcement are made, tested and commissioned. The formwork is cleaned and the necessary scaffolding is ready for use. The equipment and materials are prepared. The scope of work is the following: measuring and moving, concreting, cleaning and aftercare. According to Ratu production data

tables speed of work for walls using a concrete pump is 0.33 ph/m³. The correction factor TL3 in this case is between 1.05 and 1, but closer to 1.05. All information is taken from tables of Ratu production data which are shown below.

Трудозатраты ТЗ на объекте нового строительства

Бетонирование	чч/м ³
Ростверки и низкие фундаментные стены	
- бетонирование с применением насоса бетононасоса	0,25
- бетонирование с применением бетононасоса бетононасоса	0,28
- бетонирование с применением бетононасоса бетононасоса	0,33
Стены и высокие фундаментные стены	
- бетонирование с применением насоса бетононасоса	0,34
- бетонирование с применением бетононасоса бетононасоса	0,39
- бетонирование с применением бетононасоса бетононасоса	0,49
Колонны	
- бетонирование с применением бетононасоса	0,25
- бетонирование с применением бетононасоса бетононасоса	0,24
Плиты	
- бетонирование с применением бетононасоса	0,20
- бетонирование с применением бетононасоса бетононасоса	0,21
Плиты основания	
- бетонирование с применением бетононасоса	0,17

speed of work for walls using concrete pump

На объекте нового строительства на трудозатраты влияют

Объем работ по бетонированию, м ³	25	50	100	200	800
Ростверки, фундаментная стенка	50	100	200	400	1600
стена, колонна	50	100	200	400	1600
плита, балка	50	100	200	400	1600

коэффициент	1,15	1,10	1,05	1,00	0,90
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TL3 factor

Concreting
0.33218.5 = 72.105 ph
1.04572.1 = 75.344 ph
$\frac{75.35}{80} = 0.942$ shif

From the calculations above it can be seen that the team of ten workers completes the concreting step in less than one eight hour working day. Also, the time for concrete to harden should be taken into account before the formwork will be taken away.

The next step is to complete the ceiling and then monolithic screed. This stage of the project can be divided into two parts. First, the ceiling has to be done. The work for the ceiling is divided into two parts. The first part for completing the ceiling is assembling a formwork for it. The formwork needed for the ceiling is 208 m² for one floor. The speed of assembling this kind of formwork is 0.28 ph/m²; the speed of disassembling and cleaning is 0.3 ph/m². TL3 factor for this case is 1.2. Then concrete should be poured to complete the ceiling structure. The speed of concreting the ceiling with a concrete pump is 0.21 ph/m³ and TL3 factor for is between 1.1 and 1.05, somewhere in the middle. The second stage of this project is completing of the monolithic screed. Several things are taken into account to calculate this stage. The following things that have to be done and their speed is the following: measurements-0.11 ph/m², concreting using a concrete pump and leveling-0.06 ph/m², vacuum treatment-0.03 ph/m², rubbing the concrete surface manually-0.03 ph/m², cleaning of equipment and care-0.03 ph/m², evening of the floor for this case-0.07 ph/m². As previously, this task will be done by 10 workers. Using all this information the production data for this stage can be easily calculated. The calculations are shown below.

Formwork for ceiling
$208 \times 0.58 = 120.64 \text{ ph}$
$1.2 \times 120 = 144 \text{ ph}$
$\frac{144}{80} = 1.8 \text{ shifts}$
Concreting of ceiling
$115 \times 0.21 = 24.15 \text{ ph}$
$1.075 \times 24.15 = 25.961 \text{ ph}$
$\frac{25.961}{80} = 0.325 \text{ shifts}$
Completing of monolithic screed
$210 \times 0.33 = 69.3 \text{ ph}$
$69.3 \times 1.15 = 79.695 \text{ ph}$
$\frac{79.695}{80} = 0.996 \text{ shifts}$

Both steps of this stage will need concrete to harden. For each step it is approximately two days are needed for concrete to harden. As a result with the use of 10 construction workers this stage of the project will be completed in a bit more than seven or eight hours long working shifts.

After completing the monolithic screed and ceiling the next step is initial leveling of the concrete surface. Initially walls are ready, the formwork is removed from the structure, Concrete surfaces are not treated, materials and needed equipment are on site. The scope of work including measurements, moving and cleaning is the following: polishing of concrete surfaces, initial leveling and sealing of concrete surfaces and spray application of concrete. The speed of moving, checking and measuring is 0.003 ph/m² and 0.006 ph/m². In case the normal condition of formwork speed of pol-

ishing concrete is 0.02 ph/m², speed for initial leveling and sealing of concrete surfaces is 0.08 ph/m², speed of spray application is 0.048 ph/m² and cleaning speed is 0.003 ph/m². The correction factor TL3 for the given case is 1.1. Pictures with Ratu tables shown below give information needed for the calculations.

Трудозатраты ТЗ на объекте нового строительства

Подготовительные работы	чч/м ²	
- перемещения	0,006	
- проверка, обмеры	0,003	moving, checking and measuring
Шлифовка		
- опалубка в хорошем состоянии	0,008	
- опалубка в нормальном состоянии	0,020	speed of polishing concrete
- опалубка в плохом состоянии	0,030	
- техника элементов	0,008	
Предварительное выравнивание и заделка		speed for initial leveling and sealing of
- опалубка в хорошем состоянии	0,050	concrete surfaces
- опалубка в нормальном состоянии	0,080	
- опалубка в плохом состоянии	0,100	
- техника элементов	0,030	
Бетонирование распылением		
- опалубка в хорошем состоянии	0,030	
- опалубка в нормальном состоянии	0,048	speed of spray application
- опалубка в плохом состоянии	0,060	
- техника элементов	0,018	
Заключительные работы		
- очистка инвентаря, уборка	0,003	

На объекте нового строительства на трудозатраты влияют

Общий объем бетонных поверхностей, подлежащих выравниванию, м ²	1000	2000	4000	8000	
коэффициент	1,10	1,05	1,00	0,95	TL3 factor

Initial leveling of concrete surfaces
ph
$0.006 + 0.003 + 0.02 + 0.08 + 0.048 + 0.003 = 0.16$ m ²
$0.16840 = 134.4$ ph
$1.1 \cdot 134.4 = 147.84$ ph
$\frac{147.84}{80} = 1.848$ shift

From the calculations above can be seen that the team of ten workers will complete this step of working process for less than two days.

The last step for our project is cutting. For this particular case 26 meters have to be cut. Initially state all structures are mounted, framework is disassembled; materials and equipment are on site. The scope of work for the following step is measurement, preparation of equipment, cutting and cleaning. Assembling speed of measurement, preparation of equipment and so is 0.2 ph/object, speed of cutting is 0.4 ph/m, speed of cleaning is between 0.1 and 0.4 ph/object. The numbers are taken according to Ratu Production data. The correction factor TL3 for the project is close to 0.9. Pictures with Ratu tables shown below give information needed for the calculations.

Трудозатраты ТЗ на объекте нового строительства

Подготовительные работы		чч/объект	
- обмеры, подготовка оборудования и пр.		0,20	measurement, preparation of equipment and so
- перемещения подъемником		0,15	
- перемещения по лестнице		0,30	
Алмазное бурение			
чч/отверстие			
	Глубина бурения		
Размер отверстия	менее 250 мм	400...600 мм	
- 30...60 мм	0,30	0,40	
- 80...125 мм	0,40	0,50	
- 125...175 мм	0,50	0,60	
- 175...300 мм	0,65	0,90	
- 300...450 мм	0,90	1,10	
Алмазное спиливание		чч/пог. м	
На бетонной стене			
- глубина спиливания 100 мм		0,40	speed of cutting
- глубина спиливания 150 мм		0,50	
- глубина спиливания 200...250 мм		0,60	
- глубина спиливания 300 мм		0,80	
Кирпичная стена 130 мм		0,10	
Перекрытие			
- глубина спиливания 200...250 мм		0,25	
- глубина спиливания 300 мм		0,40	
Штробление долблением, штрабление пола		0,80	
Заделка			
Заделка штрабы в полу		0,60	
Заделка штрабы в полу, корректирующий бетонный раствор			
- без опалубки		0,30	
- с применением опалубки в углах		0,50	
Заполнение гипсовым раствором			
за один раз	0,40 чч/м² заделки		
Заделка трехслойной штукатуркой	2,00 чч/м² заделки		
Перемещения мусора и уборка		0,10...0,40 чч/перемещение	cleaning

На объекте нового строительства на трудозатраты влияют

Объем работ по алмазному бурению на объекте				
Количество отверстий, шт.	4	10	30	>100
коэффициент	1,5	1,1	1,0	0,9
Объем алмазного спиливания на объекте				
спиливания, пог. м	<3	3...	...20	>30
коэффициент	1,2	1,0	0,9	

TL3 factor

Cutting	
	ph
0.2+ 0.3= 0.5	object
0.55 = 2.5	ph
0.426 = 10.4	ph
0.912.9= 11.61	ph
$\frac{11.61}{80} = 0.145$	shif

From the calculations presented above can be seen that the same team of ten workers will do it for 0.15 of 8 hours working day.

From the information according to the calculations it can be seen that with Ratu system the work will be done for 15,325 8 hours working shifts which is quicker than in real life. According to the information of the project work was done in 17,8 8 hours shifts.

5.1.2 Scheduling

Scheduling is one of the most important steps of the project management. It has to be prepared before the construction work starts. It demonstrates the sequence of construction processes and steps and which of those are co-dependent or can be done simultaneously. Therefore it is helping to use project time with a maximum efficiency and complete the project as soon as possible, at the same time meeting all the required quality standards. As said previously scheduling will be made only for one completed floor using the production data calculations completed using Ratu book.

The project taken for application consists of the following tasks, which have to be done in order to complete the construction of monolithic walls:

- Clearing
- Formwork
- Reinforcement
- Concreting
- Completing of monolithic screed and ceiling
- Installations of prefabricated concrete structures
- Initial leveling of concrete surfaces
- Polishing, cutting and filling of irregularities

This particular project does not require all works from the list. Using information from the calculations completed by using Ratu production data book schedule (Figure 29) for one floor of a building can be completed. The schedule is shown below. In the graph can also be seen that some work can be completed simultaneously.

Black lines show assembling and disassembling of formwork, which takes for each 3.05 shifts, the red line shows reinforcement, which takes 4.28 shifts, the yellow line shows concreting, which takes 0.92 and 0.33 shifts, the orange lines shows assembling and disassembling formwork for ceiling, which takes 0.9 shifts for each, the pink line is for concreting of ceiling, which is 0.33 shifts, with the grey line shown completing of monolithic screed, which is 0.99 shifts, with the green line shows hardening of concrete for walls, ceiling and monolithic screed, which in general takes 6 shifts, the blue line shows initial leveling, which takes 1.848 shifts and the purple line shows cutting, which takes 0.145 shifts. The graphic shows timing of each step completed by two teams of 5 people. The time of completing the task is three weeks.

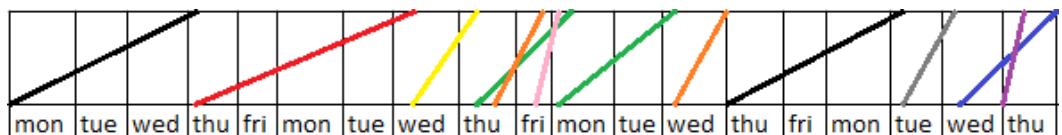


Figure 29 Schedule

5.1.3 Work descriptions

Work descriptions show the scope of work needed. For a project which is taken as an application the following work has to be done:

- Formwork. It includes the preparations, installation, strengthening, and ligaments, disassembling and cleaning of formwork. It also includes other work, such as measuring work, scaffolding, coating agents, which improves the separation of the formwork, the implementation of construction joints and through-holes, technological openings, mounting clamps, as well as the transfer, organizing and linking accessories.
- Reinforcement. It includes work piece fixtures on a construction site, cutting, bending of reinforcement, installation, binding, blank clamps preparations, also ancillary works, such as acceptance and moving.
- Concreting. It includes receiving of concrete, transporting, concreting, sealing and initial alignment and also ancillary works, such as installation of scaffolding for concreting, formwork cleaning, pouring water on formwork before concreting. Also curing, moisturizing and protecting concrete.
- Completing of monolithic screed. To complete the monolithic screed the first step is to build a formwork for the ceiling and make concreting for it. The work also includes the placement of concrete, protective layer of concrete, leveling layer and completing the screed, which has to be done as a separate phase of the work, completing of cement mosaic, applying self-leveling compounds and rubbing the concrete surface either manually or mechanically and also leveling of vacuum concrete. The work includes measurements performed by the workers, marking and looking up for concrete.
- Initial leveling of concrete surfaces. The work includes initial leveling of concrete surfaces for finishing with protection devices and scaffoldings and also grinding before finishing concrete surfaces.
- Polishing, cutting and filling of irregularities. The work includes polishing, cutting and filling uneven concrete surfaces, performed in new construction and also installations of scaffoldings, installation of protection and cleaning.

6 CONCLUSION

After a detailed analysis of data, acquired from experience of construction field professionals and relevant information sources on the internet, it was concluded that using innovative technologies in construction in most cases improves the cost-efficiency and the general quality of the project. In a long-term perspective the use of innovative technologies reduces the cost

of later renovation and maintenance of the structure. However, in the modern construction environment there is still a certain degree of resistance to innovative technologies among specialists due to unwillingness to change well-established work habits. Nevertheless, it is clear that traditionally used technologies should progress and gradually be replaced by newer ones despite the comfort of their use. This will ensure the quality growth in all important aspects of construction project and contribute to sustainability of a construction on a global scale. This progress must be based on experience of previous generations and supported by empirical data extracted from project documentation. The project implementation process must be documented in order to estimate financial, environmental and structural efficiency of innovative technology use and contribute to its further improvement. In order to gain maximum benefit from using innovative technologies in construction corresponding guidelines and application principles usually stated by manufacturers have to be comprehended and followed strictly by everyone in a construction design office to a construction site worker. Every project has to be approached individually and practicability of using innovative technologies should be assessed carefully.

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Appendices have their own style:

Appendix 1

TITLE OF APPENDIX

There is no numbering on the Appendix pages.